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To: Authorized Distribution

Subject: JPL CONTRACT 954995
FOURTH QUARTERLY PROGRESS REPORT

Gentlemen:

Enclosed is the Fourth Quarterly Progress Report. Period covering: January 1, 1979 to March 31, 1979 by Dow Corning Corporation for Jet Propulsion Laboratory.

Very truly yours,

W. E. Dennis

William E. Dennis
Principal Investigator

/dlh

FOURTH QUARTERLY PROGRESS REPORT

Period Covered: January 1, 1979 - March 31, 1979

DEVELOP SILICONE ENCAPSULATION SYSTEMS FOR TERRESTRIAL SILICON SOLAR ARRAYS

JPL Contract 954995

For

JET PROPULSION LABORATORY
4800 Oak Grove Drive
Pasadena, California 91103

The JPL Low-cost Silicon Solar Array Project is sponsored by the U.S. Department of Energy and forms part of the Solar Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost solar arrays. This work was performed for the Jet Propulsion Laboratory, California Institute of Technology by agreement bewtween NASA and DOE.

by

DOW CORNING CORPORATION

Midland, Michigan 48640

May, 1979

I. SUMMARY AND REVIEW

This study for Task 3 of the Low Cost Solar Array Project (LSA) funded by DOE is directed toward the development of a cost effective encapsulation system for photovoltaic modules using silicone based materials. It is a cooperative effort between Dow Corning Corporation, the major supplier of silicones and silicone intermediates, and Spectrolab, a leading photovoltaic manufacturer.

This contract effort is divided into four sequential tasks:

1) A Technology Review
2) Generation of Concepts for Screening and Processing Silicone Encapsulation Systems
3) Assessment of Encapsulation Concepts
4) Evaluation of Encapsulation Concepts

The Technology Review was completed and reported in the First Quarterly Report. The Generation of Concepts for Screening and Processing Silicone Encapsulation Systems was completed during the Second Quarter. The Assessment of Encapsulation Concepts was started during the Third Quarter and data on outdoor dirt pickup and temperature/humidity cycling obtained.

Progress during the Fourth Quarter.

1) Samples of silicone materials with known weatherability have been exposed in our Atlas Filtered Weather-Ometer® for over 4,000 hours. During the current quarter all of the silicone resins with appreciable phenyl content showed more degradation than samples exposed to natural weathering. All of the elastomeric silicone materials with small or negligible phenyl content did not visibly change.

2) After 75 temperature cycles from room temperature to 40.5°C at 90-95% relative humidity there was no appreciable change in the short circuit (I_{sc}) cell currents using any of the encapsulation concepts.

3) After 50 days of exposure to 90-95% relative humidity at 70°C these samples had I_{sc} values within experimental error of the initial values.

4) The outdoor exposure samples have attained a total of 200 days exposure and the I_{sc} values show relatively wide variations. One outdoor exposure sample failed due to loss of adhesion of the DOW CORNING® X1-2561 encapsulant to the glass substrate. This caused an open circuit due to lifting of the metallization from the cell surface. The only distinct downward trend in I_{sc} which could be attributed to dirt pickup was with the cell coated with DOW CORNING® 3140 RTV, a soft elastomer.

5) The temperature cycling test from -40°C to +90°C caused visible cracks in all of the encapsulation concepts except for DOW CORNING® Q1-2577 as a protective coating both on Super Dorlux® and under Solatex® glass, DOW CORNING® 808 Resin under Solatex Glass and the blend of DOW CORNING® 840 Resin with B48N acrylic resin on Super Dorlux®. Cracks in all the other encapsulation systems were visible after five cycles and became progressively worse through 15 cycles. This stress test is still in progress.

6) UV absorbing agents were incorporated in DOW CORNING® Q1-2577, DOW CORNING® 840/B48N and DOW CORNING® 808 Resin. The UV screening agents used were Permasorb® MA, Uvinul N-539 and Uvinul N-35. All of these show promise for use as screens to protect photosensitive polymers.

II. INTRODUCTION

The goal of this program is the development of a cost effective encapsulation system for photovoltaic modules based on silicone materials consistent with the LSA cost goals of \$0.50/watt by 1985. It is a co-operative effort between Dow Corning Corporation and Spectrolab.

The effort is divided into four sequential tasks:

1) Technology Review
2) Generation of Concepts for Screening and Processing Encapsulation Systems
3) Assessment of Encapsulation Concepts
4) Evaluation of Encapsulation Concepts

The Technology Review was completed and reported in the First Quarterly Report. Several promising encapsulation systems and silicone based materials appropriate for use in these systems were identified and reported in the First Quarterly Report. Concepts for Screening and Processing Silicone Encapsulation Systems were generated during the Second Quarter and reported in the Second Quarterly Report. The Assessment of the ability of these encapsulation systems to protect solar cells was started in the Third Quarter and is still continuing.

The stress test which caused the largest number of failures, judged by the formation of large cracks in the protective coating, was the thermal cycling test from -40°C to +90°C. This test was started in the Fourth Quarter and after only five cycles all of the modules except four had visible cracks. The only protective coating which remained unchanged on both Super Dorlux® and Solatex® Glass through 15 thermal cycles was DOW CORNING® Q1-2577 Conformal Coating.

All of the encapsulation systems have provided good results throughout all of the other stress tests with a couple of exceptions. The solventless experimental resin, DOW CORNING® X1-2561, delaminated from the glass substrate during the outdoors exposure studies designed to monitor dirt pickup which caused an open circuit in the cells and DOW CORNING® 3140 RTV elastomer shows a downward trend in I_{SC} due to dirt pickup in these outdoor exposure studies.

The other stresses, humidity/temperature cycling and high humidity-high temperature exposure provided no statistical difference between the encapsulation systems.

The feasibility of incorporating UV absorbing agents in soil resistant silicone based protective coatings was demonstrated during the Fourth Quarter. The coatings containing UV absorbers were shown to protect photosensitive pottants.

The Weather-Ometer® stressing of silicones with known weatherability performance reached 4,500 hours of exposure time during the current quarter. Around 4,000 hours all of the resins containing appreciable amounts of phenyl-silicon groups were noticeably affected. The check ratings of these samples were higher than those reported after 13 years exposure in Texas or 10 years exposure in Midland. The elastomeric silicone materials, in contrast, did not visibly change after 4,000 hours exposure although both the tensile strength and modulus of one elastomer which was measured, 132U, were slightly lower. These elastomeric materials have small or negligible phenyl contents.

III. RESULTS AND DISCUSSION

A. Weather-Ometer® Stressing vs. Weathering History of Silicone and Silicone Modified Materials.

Table I shows a comparison of the results obtained from samples exposed outdoors and those obtained using an Atlas Filtered Carbon Arc Weather-Ometer®.

None of the samples showed any appreciable effects from exposure in the Weather-Ometer® until 3,000 hours. Between 3,000 and 4,200 hours all of the resin coatings showed more signs of degradation than any of the coatings weathered naturally for up to 13 years.

Usually the resins degraded due to poor check ratings and loss of 60° gloss. Both of these signs of degradation are indicative of higher surface crosslinking and/or oxidation attributed to UV radiation.

Between 2,500 and 3,000 hours large cracks became visible in DOW CORNING® 901 Resin exposed as a clear coating on an aluminum panel. A sample of DC® 901 exposed as a clear coating on woven glass cloth remained clear and transparent at 3,000 hours exposure. By 3,500 hours exposure, however, this sample became embrittled, lost adhesion to the glass substrate and most of the resin was missing from the glass cloth.

DOW CORNING® 808 Resin had no checking at 2,500 hours but between 2,500 hours and 3,000 hours dropped to a check rating of 7 meaning that the entire surface was covered with microcracks. The checking did not become any worse up to 4,200 hours exposure, however between 3,500 and 4,000 hours the 60° gloss dropped from 90% of the original value to 68% indicating additional loss in surface properties.

DC® 996 resin had the most significant change in checking between 2,500 and 3,000 hours of any of the resins tested. The check rating dropped from 10 (no checking) to 4 (visible cracks on 50% of the surface area). This resin also dropped from no loss of 60° gloss at 2,500 hours to 15% loss at 3,000 hours. By comparison after 10 years exposure in Midland, Michigan this resin had no loss of gloss and a check rating of 6.

The blend of 10% DC® 840 - 90% B66 acrylic resin from Rohm and Haas also showed degradation due to checking between 2,500 and 3,000 hours when the check rating dropped from 10 to 6. No additional degradation was observed in either gloss or checking at 3,500 hours exposure. However, at 3,500 hours 80% of the film was lost from the aluminum panel due to poor adhesion. In contrast, a sample of this resin blend had no loss of gloss or checking after 13 years exposure in Texas.

None of the elastomers show any visual signs of degradation after 4,200 hours exposure in the Weather-Ometer®. Samples of 132U silicone elastomer, which were removed from the Weather-Ometer® at periodic intervals through 3,786 hours, were measured for tensile strength and elongation. There is a relatively large variation in the values obtained but the data indicates a 10 to 20% loss in both tensile strength and elongation.

Test specimens of all the elastomers exposed in the Weather-Ometer® will be removed after 4,500 hours exposure and tested. These include specimens exposed in both stressed and unstressed states. This experiment will disclose whether minor changes in formulation have a significant effect on the UV stability of silicone elastomers on whether the chemical structure element, polydimethylsiloxane, provides inherent UV stability.

B. Humidity/Temperature Cycling Exposure

Encapsulation concepts using DOW CORNING® Q1-2577, X1-2561, DC® 840/B48N, DC® 808 and RTV 3140 on Super Dorlux and under Solatex Glass were cycled from room temperature to 40.5°C at 95% relative humidity. All of

these systems were cycled 75 times and there were no statistical decreases in short circuit current, see Tables II and III. Random fluctuations were observed which initially were thought to be due to time of sampling, that is, samples removed at 40.5°C vs. samples removed at room temperature. However, further analysis revealed that the fluctuations were probably an artifact of the measurement technique. The short circuit current measurements are obtained by illuminating the cells for a short period of time (approximately 2-3 seconds) using a 400 watt ELH lamp. It was observed that the cell position during this measurement was extremely critical. Differences in cell placement of 1-2 mm gave up to 10% variation in I_{sc} values. This sensitivity to cell position was overcome by moving the target area back from the light source several inches. An illumination of 1,000 watts/m^2 can still be obtained measured with a standard reference cell from NASA Lewis Research Center and the target area is twice as large as the cell's area. The cell position can be varied up to 1 cm with less than a 10% change in I_{sc}.

C. Exposure at High Humidity/High Temperature

The specimens using various encapsulation concepts from above after the temperature cycling stress from room temperature to 40.5°C at 95% relative humidity were stressed in the same humidity chamber at a constant 95% relative humidity and 70°C for 50 days. After this period, there was again no significant change in I_{sc}, see Tables IV and V. These results show that there were no chemical species present around the encapsulated cells which would cause serious corrosion in humid environments and that the encapsulants themselves were also free of chemical contaminants which would cause rapid corrosion in a wet environment.

In order for these high humidity stresses to differentiate between potential encapsulation concepts much higher stresses need to be used. All of the encapsulation concepts appear to provide adequate protection from moisture induced failure mechanisms. The additional criteria of UV stability and relief of stress during thermal cycling are more likely to discriminate between the encapsulation concepts.

D. Outdoor Exposure Stress

Samples of silicone based materials were used to coat photovoltaic cells on a glass substrate. These cells were monitored for change in I_{SC}. These changes should correspond to losses due to dirt pickup, see Table VI. The precipitation was also monitored and these data are shown in Figures 1-6.

In many cases an increase in I_{SC} follows a period of precipitation. The measurement technique caused some variation because the beam of light used to measure I_{SC} was only slightly larger than the cells. These variations were eliminated by increasing the size of the illuminated area and the measurement site as mentioned earlier.

Small differences, approximately 10%, in I_{SC} caused by dirt pickup can be seen using this improved measurement technique and effects of natural washing due to precipitation should correlate even better than previously.

One encapsulation material shows a definite trend downward in I_{SC} with length of outdoor exposure. This silicone elastomer, DOW CORNING® 3140 RTV is a softer elastomer than SYLGARD® 184 and was included to see if dirt pickup could be related to modulus of encapsulant. This lower modulus elastomer does appear to decrease in power with increased outdoor exposure. Unfortunately the range of moduli represented by the

relatively soft SYLGARD® 184 and relatively hard DC® 808 resin do not correlate with dirt pickup due to outdoor exposure. After 216 days outdoor exposure, the I_{SC} of the cell encapsulated with SYLGARD® 184 is 441 milliamps and that of DC® 808 resin is 426 milliamps, see Table VI.

The cell encapsulated with DC® X1-2561, an experimental solventless resin, failed due to an open circuit caused by the DC® X1-2561 lifting the metallization from the cell surface. The coating of DC® X1-2561 used in this outdoor exposure test was quite thick, approximately 40 mils, and its adhesion to the glass substrate was poor.

This experimental resin functions well as the cell adhesive for bonding cells to a glass superstrate. The glue line is clear, void free, and survives both humidity and thermal cycling stress.

E. Thermal Cycling Stress

Modules prepared by encapsulating two-cell strings on Super Dorlux® and under Solatex® Glass with the silicone based encapsulation materials were thermally cycled from -40°C to 90°C using the schedule recommended by the Jet Propulsion Laboratory. The materials used on both Super Dorlux® and Solatex® glass were: DOW CORNING® Q1-2577, 808 resin, 840/B48N and X1-2561.

After 4 thermal cycles there were only four modules which did not have visible cracks. These were modules using DOW CORNING® Q1-2577 on both Super Dorlux® and Solatex® Glass and the module using DC® 840/B48N on Super Dorlux® and the module using DC® 808 resin on Solatex® Glass.

During the eighth thermal cycle, a valve froze on our thermal cycling unit and the temperature reached -120°C. During this cycle all of the cracks on all of the modules which had cracks in the encapsulant became decidedly larger although the 4 modules without cracks remained free of defects.

After 15 thermal cycles the protective coatings on these 4 modules still remained intact.

The protective coating used in these encapsulation concepts has been referred to in this report as the encapsulation material consistent with the nomenclature normally used by the photovoltaic industry. It should be noted that in most cases the protective coatings have been applied as very thin conformal coatings. This is a more cost effective way of utilizing the silicone based materials and may provide the additional benefit of reducing the biaxial stress which increases with increased coating thickness. The coating of DC® 840/B48N used on the Super Dorlux® module which was thermally cycled was very thin and could explain why it survived.

The effect of coating thickness on resistance to cracking during thermal cycling will be assessed further next quarter.

F. UV Screening Agents

Three ultraviolet absorbing agents were incorporated into DOW CORNING® Q1-2577, DC® 840/B48N, and DC® 808 resin. These three candidate cover materials were used to assess the compatibility of UV absorbing compounds with their respective cure systems and to determine if the cured films blocked out short wavelength light and were transparent above 400 nanometers.

The three commercial UV absorbing compounds evaluated were Permasorb® MA, Uvinul N-539, and Uvinul N-35. One percent, based on solids, of these UV screening agents were incorporated into the silicone based cover materials. All combinations were completely compatible except the Permasorb® MA in DOW CORNING® Q1-2577. The DC® Q1-2577 containing Permasorb® MA cured more slowly than usual and the resulting film was slightly hazy.

The transmittances of the cured films with and without UV absorbing agents were measured and normalized to 1 mil thicknesses. These results are shown in Figures 7-12.

All of the films containing UV absorbing agents have less transmittance between 290 and 400 nanometers and almost the same transmittance above 400 nanometers as the control films.

The DC® 808 films containing Uvinul N-35 and N-539 are not much different than the control. These films of DC® 808 were cured at 100°C for two hours which probably caused the relatively low molecular weight UV absorbing compounds to vaporize.

All of the other films were air dried. Samples of DC® 808 will be cured at room temperature to see if there is a change in the absorbances due to these Uvinul absorbing agents.

All of the films containing UV absorbing agents protected cellulose acetate from UV radiation.

This was determined by coating cellulose acetate with thin films of the resin containing UV absorbing agents and exposing these samples in a filtered Weather-Ometer®. After 100 hours exposure, the area of cellulose acetate not protected by these films started to craze and check and the coated areas remained visibly unchanged.

IV. PLANS FOR NEXT QUARTER

1) The temperature cycling stress of encapsulation concepts will continue next quarter. This stress induces the largest number of failures and appears to be the most demanding stress for this type of encapsulation concept.
2) A significant portion of the effort next quarter will be directed towards the formulation of a silicone-acrylic or silicone-organic blend or copolymer which provides protection to the photovoltaic cells and which also passes the thermal cycling test. The purpose is to develop a protective coating which is inherently weatherable and lower in cost than DOW CORNING® Q1-2577 Conformal Coating.
3) Silicone-based covers containing UV absorbing agents will continue to be exposed in our filtered Atlas Weather-Ometer® during the next quarter. Both the changes in the cover material and the ability of these cover materials to provide protection to photo-oxidately unstable polymers will be determined.
4) No further humidity stress testing is planned in the next quarter.
5) The outdoor exposure studies will be continued and with our improved measurement techniques we expect to see small changes due to dirt pickup and natural cleaning due to precipitation.

   Duplicate samples of the encapsulated cells used to monitor dirt pickup are washed before measuring the I_{SC}. These samples assess the ability to recover any lose due to dirt pickup. This study will also continue through next quarter.

TABLE I

OUTDOOR VS ATLAS SUNSHINE CARBON ARC WEATHER-OMETER® (WOM)
STRESSING: EFFECTS ON PROPERTIES

RESIN OR ELASTOMER	FORM OF SAMPLE	SITE & DURATION OF EXPOSURE	CONDITION OF SAMPLE
1. DOW CORNING® 808 Resin	3-4 mil coating on aluminum panels	6 years Florida, 45° south	36% loss 60° gloss, no checking or dirt retention
		4,234 hours filtered WOM	33% loss 60° gloss, 7 check rating, no dirt retention
2. DOW CORNING® 901 Resin	6 mil coating on fine weave fiberglass	7 years Arizona, 45° south	99% of original 350-2400 NM transmission
		4M Langleys - Emmaqua	94% of original 350-2400 NM transmission
		3,524 hours filtered WOM	Resin flaked off of substrate.
3. B66 Acrylic/ DC® 840 Blend	3-4 mil coating on aluminum and steel panels	13 years Texas	Slight dirt retention, no loss gloss or checking
		7 years Florida, 45° south	High corrosion protection
		3,750 hours filtered WOM	100% coating off. No measurement
4. DOW CORNING® 996 Resin	2 mil coating on aluminum panel	10 years Midland	No loss gloss, no color change, checking rating 6.
		4,234 hours filtered WOM	69% loss 20° gloss (spots from water spray), 37% loss of 60° gloss, checking 2, no dirt retention.
5. LS 53 Rubber	1/8" thick strips-folded, stretched 20%, unstressed	20 years Florida	Slight dirt & mildew, no cracking or checking
		4,234 hours filtered WOM	No change

TABLE I - Cont.

OUTDORR VS. ATLAS SUNSHINE CARBON ARC WEATHER-OMETER® (WOM)
STRESSING: EFFECTS ON PROPERTIES

RESIN OR ELASTOMER	FORM OF SAMPLE	SITE & DURATION OF EXPOSURE	CONDITION OF SAMPLE
6. RTV 132U Elastomer	1/8" thick strips-folded, stretched 20%, unstressed	20 years Florida	Some loss of tensile and Elongation, Same as LS 53
		4,234 hours filtered WOM	Slight trace dirt
7. RTV 501 Elastomer	1/8" thick strips-folded, stretched 20%, unstressed	16 years Florida	Slight dirt retention and mildew
		4,019 hours filtered WOM	No checking
8. 55U Silastic® Rubber	1/8" thick strips-folded, stretched 20%, unstressed	19 years Florida	Slight dirt retention and mildew
		4,234 hours filtered WOM	No change
9. Silastic® 675 Rubber	1/8" thick strips-folded, stretched 20%, unstressed	19 years Florida	Slight decrease in durometer, tensile and elongation, some surface cracking
		4,234 hours filtered WOM	No change
10. RTV 781	6 mil coating on aluminum panel	20 years Wisconsin	Dirt pick up, slight lowering in durometer
Building Sealant	6 mil coating on aluminum panel	3,679 hours filtered WOM	No loss 20° gloss, some blisters

TABLE II

SUPER DORLUX SUBSTRATE MODULE DESIGN
TEMPERATURE CYCLING TEST

AT 95% RELATIVE HUMIDITY
ROOM TEMPERATURE TO 40.5°C

	Q1-2577				X1-2561				DC-840/B-48N				DC-808				RTV-3140			
	CELL 1		CELL 2		CELL 1		CELL 2		CELL 1		CELL 2		CELL 1		CELL 2		CELL 1		CELL 2	
CYCLES	Voc	Isc	Voc	Isc	Voc	Isc	Voc	Isc	Voc	Isc	Voc	Isc	Voc	Isc	Voc	Isc	Voc	Isc	Voc	Isc
0	551	376	573	460	561	399	569	403	586	408	575	472	574	339	576	380	567	472	570	430
5	580	378	596	492	581	515	588	506	590	401	581	470	595	470	584	382	0	0	574	453
15	567	378	595	492	567	393	574	415	592	401	577	436	582	315	591	380	-	-	587	517
25	573	370	591	478	567	391	571	393	586	303	577	459	587	341	577	353	-	-	577	427
34	568	316	589	427	567	381	572	381	588	335	571	292	575	236	575	270	-	-	575	333
44	573	389	590	515	577	550	570	427	589	340	574	488	571	351	569	395	-	-	574	474
54	577	392	593	495	571	405	574	428	591	424	576	485	580	344	579	389	-	-	581	464
65	576	386	593	501	568	388	573	281	589	424	579	501	579	354	578	369	-	-	579	474
75	572	327	586	355	567	344	572	368	590	427	565	403	576	360	573	389	-	-	574	454

TABLE III

GLASS SUPERSTRATE MODULE DESIGN
TEMPERATURE CYCLING TEST

AT 95% RELATIVE HUMIDITY
ROOM TEMPERATURE TO 40.5°C

	Q1-2577				X1-2561				DC-840/B-48N				DC-808				RTV-3140			
	CELL 1		CELL 2		CELL 1		CELL 2		CELL 1		CELL 2		CELL 1		CELL 2		CELL 1		CELL 2	
CYCLES	Voc	Isc	Voc	Isc	Voc	Isc	Voc	Isc	Voc	Isc	Voc	Isc	Voc	Isc	Voc	Isc	Voc	Isc	Voc	Isc
0	582	423	575	386	589	474	580	504	584	466	585	394	590	466	590	472	579	438	584	463
5	587	421	592	484	596	460	584	489	588	427	585	377	595	406	591	459	586	430	591	459
15	584	428	587	499	593	473	580	501	586	440	582	381	592	416	588	426	584	443	588	470
25	580	401	586	445	590	450	579	491	579	401	581	365	587	383	589	423	582	453	586	441
34	578	413	582	475	582	411	575	455	580	411	580	379	588	411	585	429	580	433	584	460
44	580	332	568	264	588	454	575	479	578	420	579	389	587	427	584	450	580	451	583	501
54	584	441	575	367	577	314	577	460	585	368	582	381	592	380	571	270	583	446	573	347
65	583	432	573	367	575	302	579	500	582	444	581	384	589	419	571	285	582	448	572	352
75	573	405	565	374	580	373	573	384	576	350	576	330	584	335	586	341	577	417	567	336

TABLE IV

SUPER DORLUX SUBSTRATE MODULE DESIGN

STRESSED AT 95% RELATIVE HUMIDITY/70°C

Constant - 70°C/95%

Days Exposure	Q1-2577				X1-2561				DC-840/B48N				DC 808				3140/3110			
	A Cell		B Cell		A Cell		B Cell		A Cell		B Cell		A Cell		B Cell		A Cell		B Cell	
	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}
0	573	405	565	374	580	373	573	384	576	350	576	330	584	335	586	341	577	417	567	336
2	583	433	577	392	591	470	577	450	584	464	577	332	590	413	585	413	584	440	584	434
4	578	401	579	423	592	523	575	449	583	484	584	423	591	437	587	417	584	484	579	414
8	585	461	582	439	590	468	575	426	583	453	583	396	593	448	585	437	580	436	578	391
17	581	426	578	419	593	465	577	471	583	459	584	405	588	394	578	371	581	452	585	469
24	582	427	580	428	590	468	568	338	581	407	584	345	591	401	579	391	582	434	587	458
32	574	376	581	449	591	469	575	413	583	442	583	386	589	388	581	403	583	457	576	374
50	576	401	577	397	579	430	576	392	575	343	580	360	584	406	579	405	578	462	583	451

*Glass Superstrate

V_{oc} - millivolts/I_{sc} - milliamps

TABLE V

GLASS SUBSTRATE MODULE DESIGN

STRESSED AT 95% RELATIVE HUMIDITY/70°C

Constant - 70°C/95%

Days Exposure	Q1-2577				X1-2561				DC-840/B48N				DC 808				3140/3110			
	A Cell		B Cell		A Cell		B Cell		A Cell		B Cell		A Cell		B Cell		A Cell		B Cell	
	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}
0	572	327	586	355	567	344	572	368	590	427	565	403	576	360	573	389	- 0	-	574	454
2	577	395	592	485	572	444	578	452	590	438	577	483	581	397	584	428	--	--	581	488
4	582	438	597	532	578	480	583	505	590	415	573	456	582	398	582	445	--	--	583	523
8	580	433	594	516	578	477	580	479	591	437	577	502	584	421	581	422	--	--	586	423
17	578	391	590	455	577	451	581	441	588	380	571	398	581	398	582	386	--	--	580	476
24	580	415	588	422	579	438	576	396	587	396	573	460	575	350	581	426	--	--	580	471
32	578	386	593	492	573	386	579	437	589	426	575	463	577	335	580	381	--	--	579	448
50	582	440	594	474	578	495	584	401	587	458	576	462	577	406	580	423	--	--	576	417

*Dorlux Substrate

V_{oc} - millivolts/I_{sc} - milliamps

TABLE VI

V_{oc} and I_{sc} versus Outdoor Exposure (Unwashed)

V_{oc} in millivolts

I_{sc} in milliamps

Days Exposure	DC-184		Q1-2577		DC-840/B48N		RTV 3140		X1-2561		Days Exposure	DC-808		DC-840/B48N	
	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}	V_{oc}	I_{sc}		V_{oc}	I_{sc}	V_{oc}	I_{sc}
0	577	489	583	469	572	473	573	487	549	458	0	577	505	574	505
11	569	474	570	451	557	474	559	471	559	478	7	561	432	555	466
26	576	448	580	441	568	453	569	430	560	412	22	567	426	566	398
37	584	463	589	450	576	439	578	547	570	396	33	570	383	573	461
44	581	465	588	452	576	450	577	452	571	396	40	576	416	570	463
53	590	469	596	434	581	416	587	449	579	378	49	581	413	578	454
60	584	515	590	494	574	445	577	438	570	406	56	576	424	574	473
66	576	500	587	484	569	441	574	464	568	349	62	572	425	570	474
81	585	425	590	423	576	342	580	403	567	315	77	577	392	575	433
96	588	451	598	445	582	413	586	423	574	369	92	582	396	578	443
108	584	458	590	429	575	413	578	357	575	364	104	577	430	577	483
124	581	359	590	388	579	419	579	420	571	330	120	577	397	578	468
134	582	469	589	461	576	434	576	417	569	356	130	574	410	572	413
150	587	468	593	460	560	413	580	409	569	329	146	576	488	577	412
163	582	428	591	434	578	436	578	408	570	308	159	576	396	573	458
175	587	451	590	379	582	424	583	421	580	111	171	580	420	576	425
201	583	439	587	397	576	398	576	376	-	-	197	573	406	570	338

FIGURE 1

OUTDOOR EXPOSURE PANELS (DC 184)

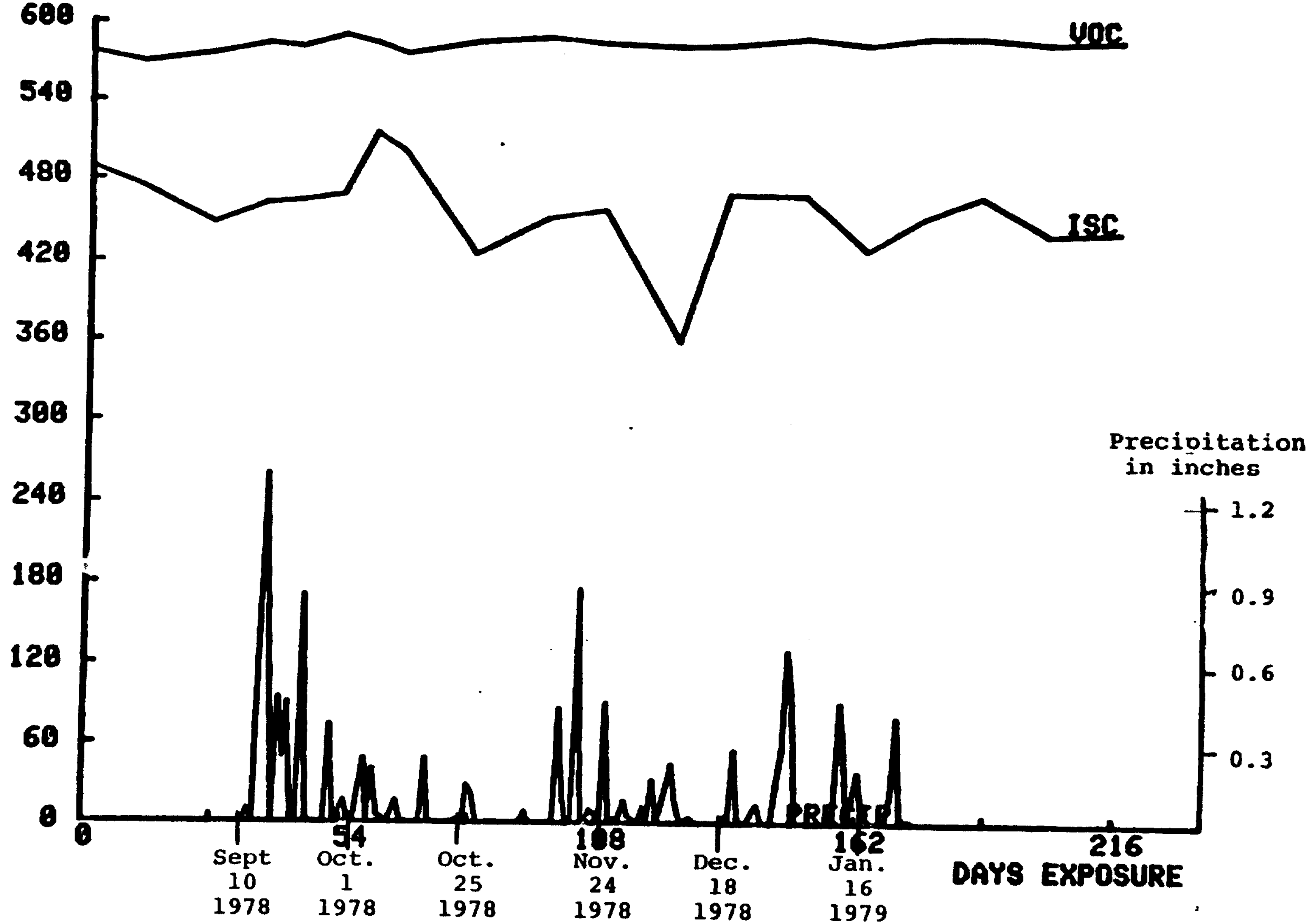


FIGURE 2

OUTDOOR EXPOSURE PANELS (RTV 3140)

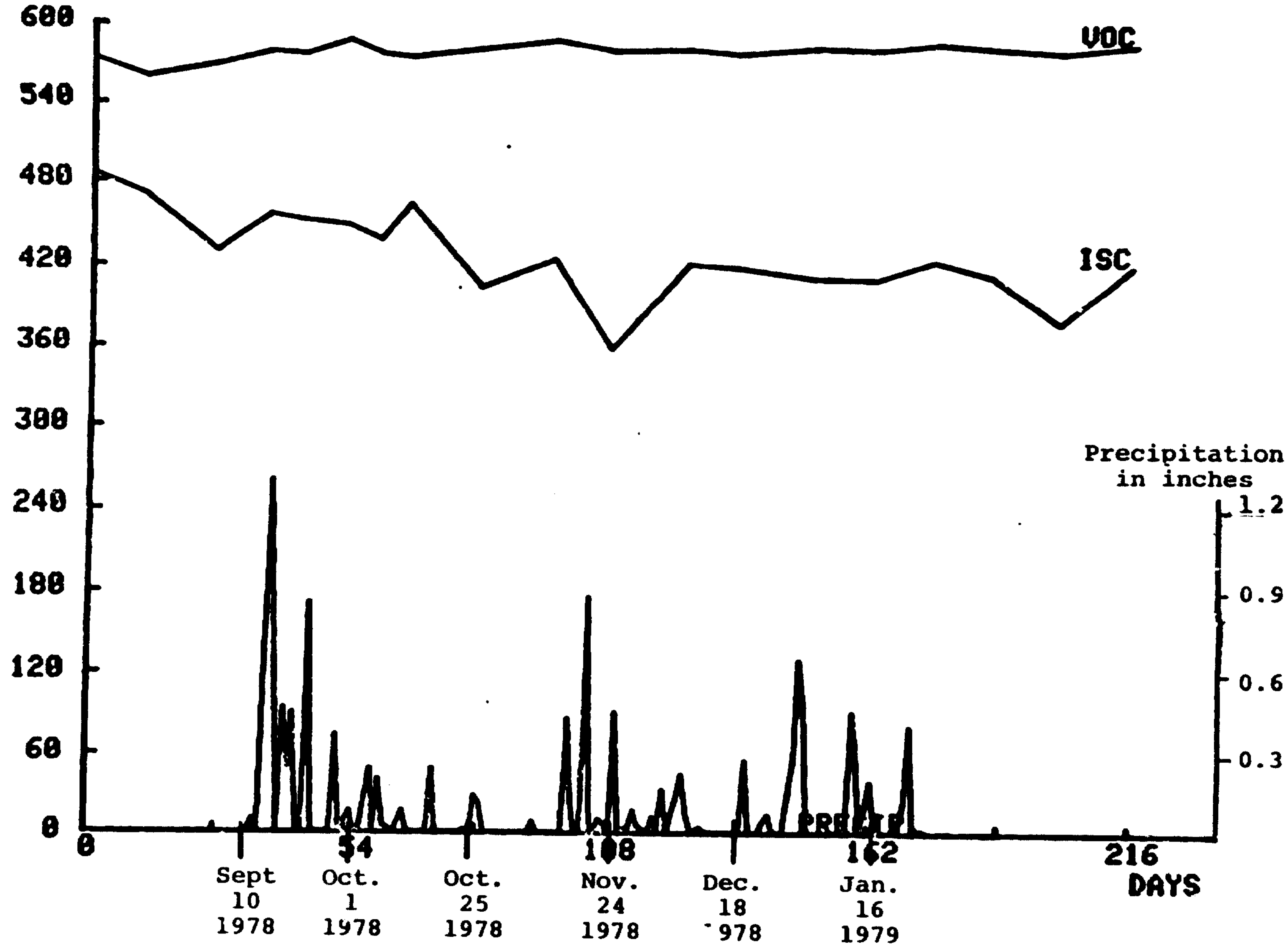


FIGURE 3

OUTDOOR EXPOSURE PANELS (Q1-2577)

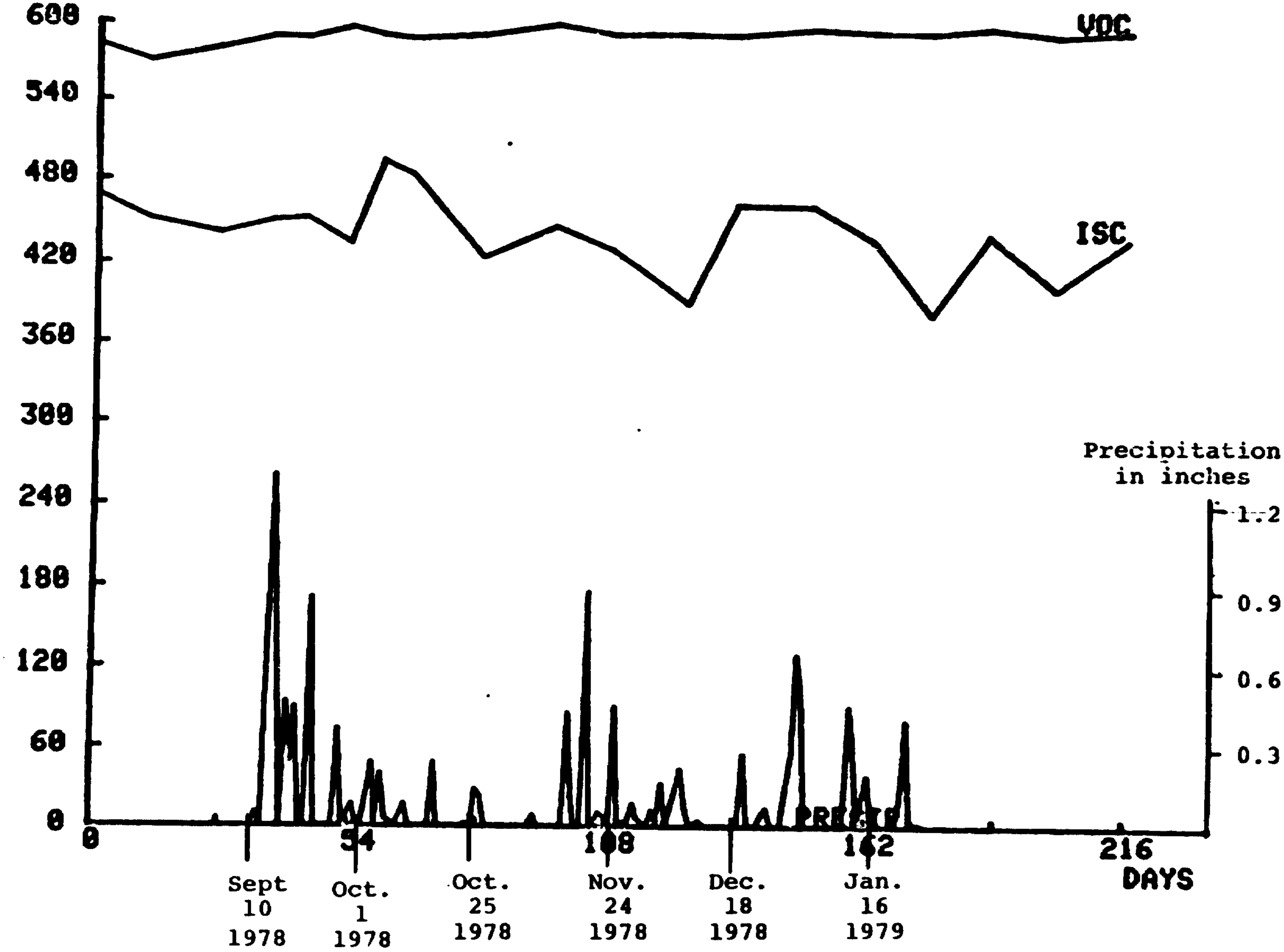


FIGURE 4

OUTDOOR EXPOSURE PANELS (DC 840/B40N)

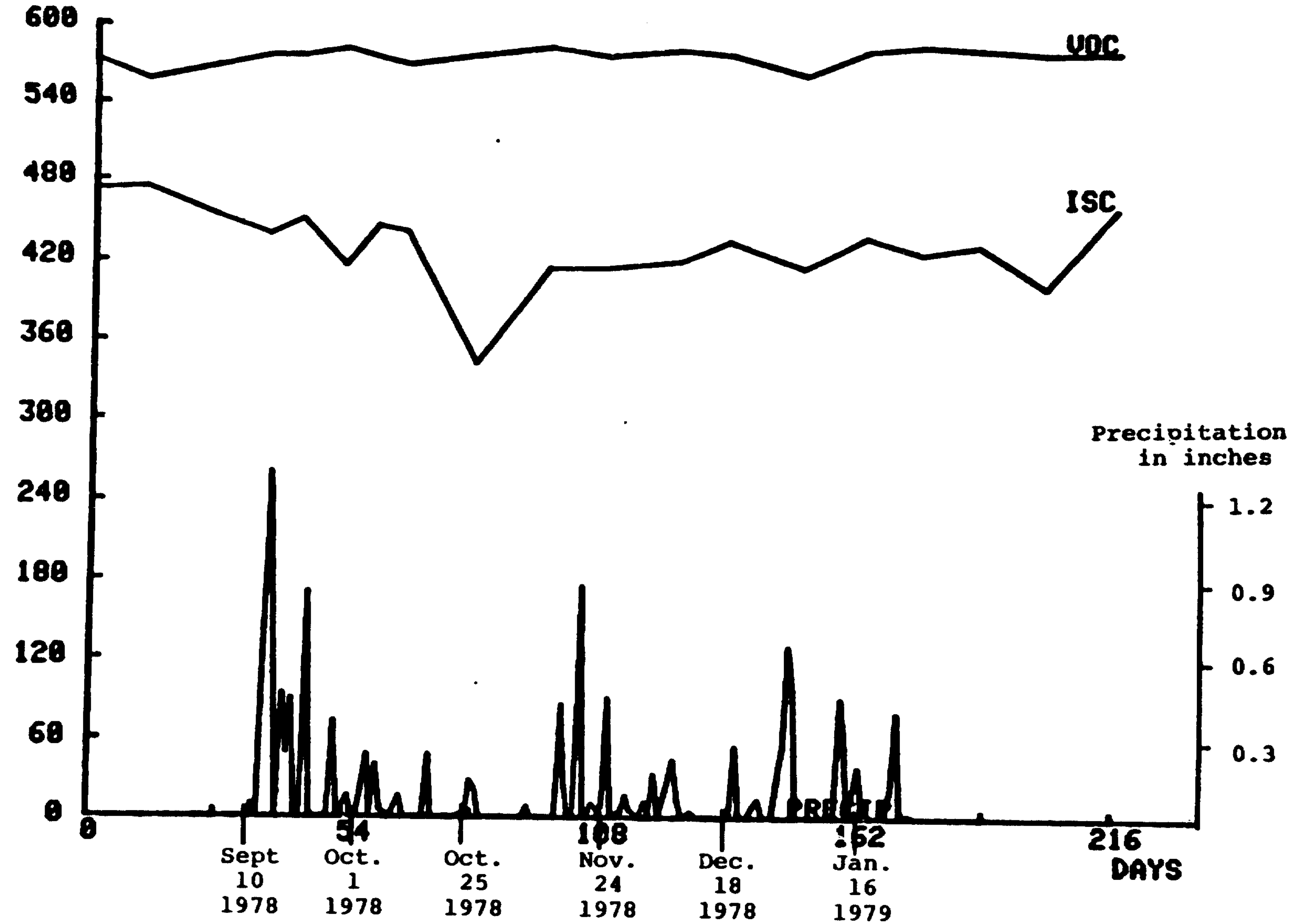


FIGURE 5

OUTDOOR EXPOSURE PANELS (DC 808)

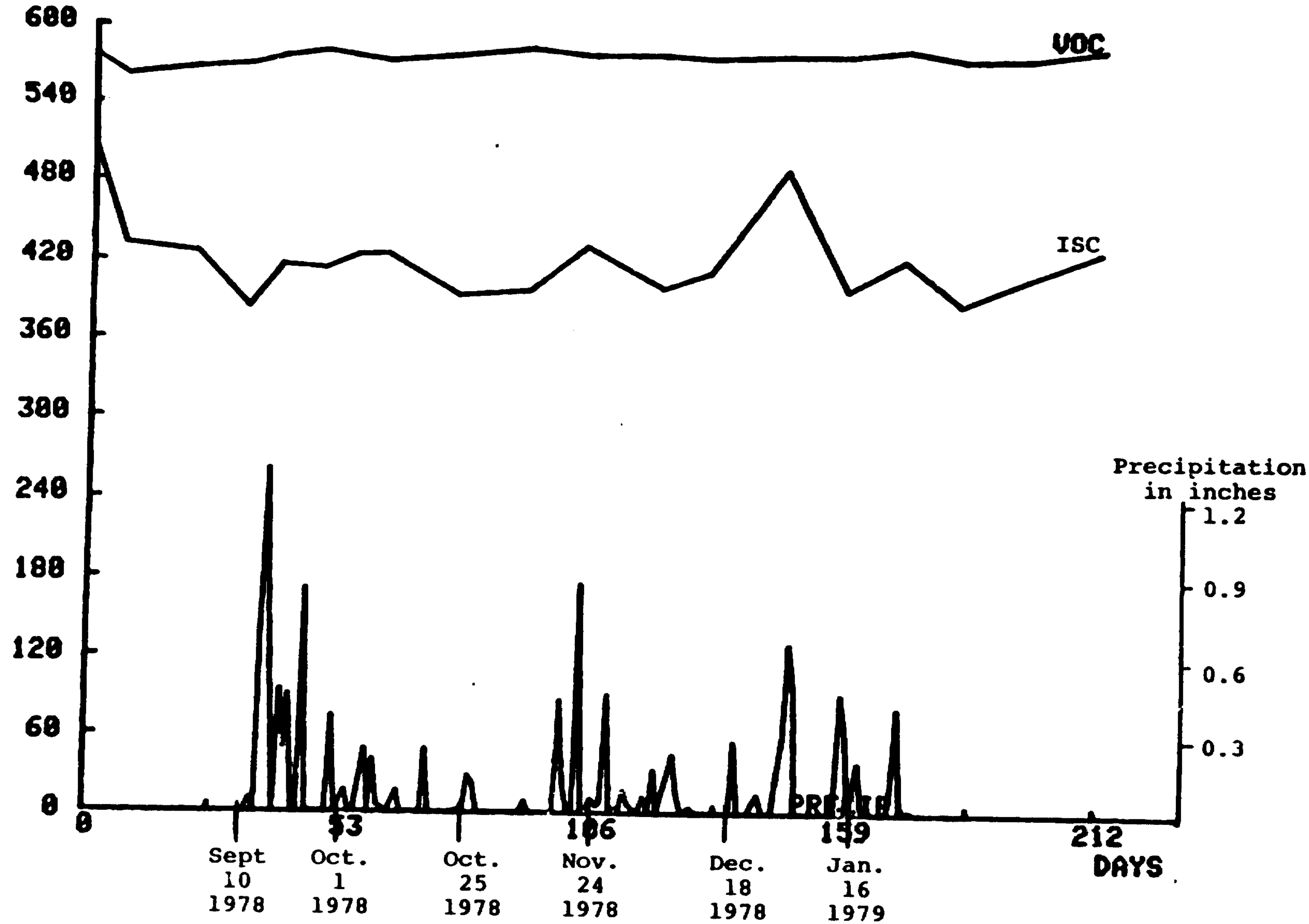


FIGURE 6

OUTDOOR EXPOSURE PANELS (X1-2561)

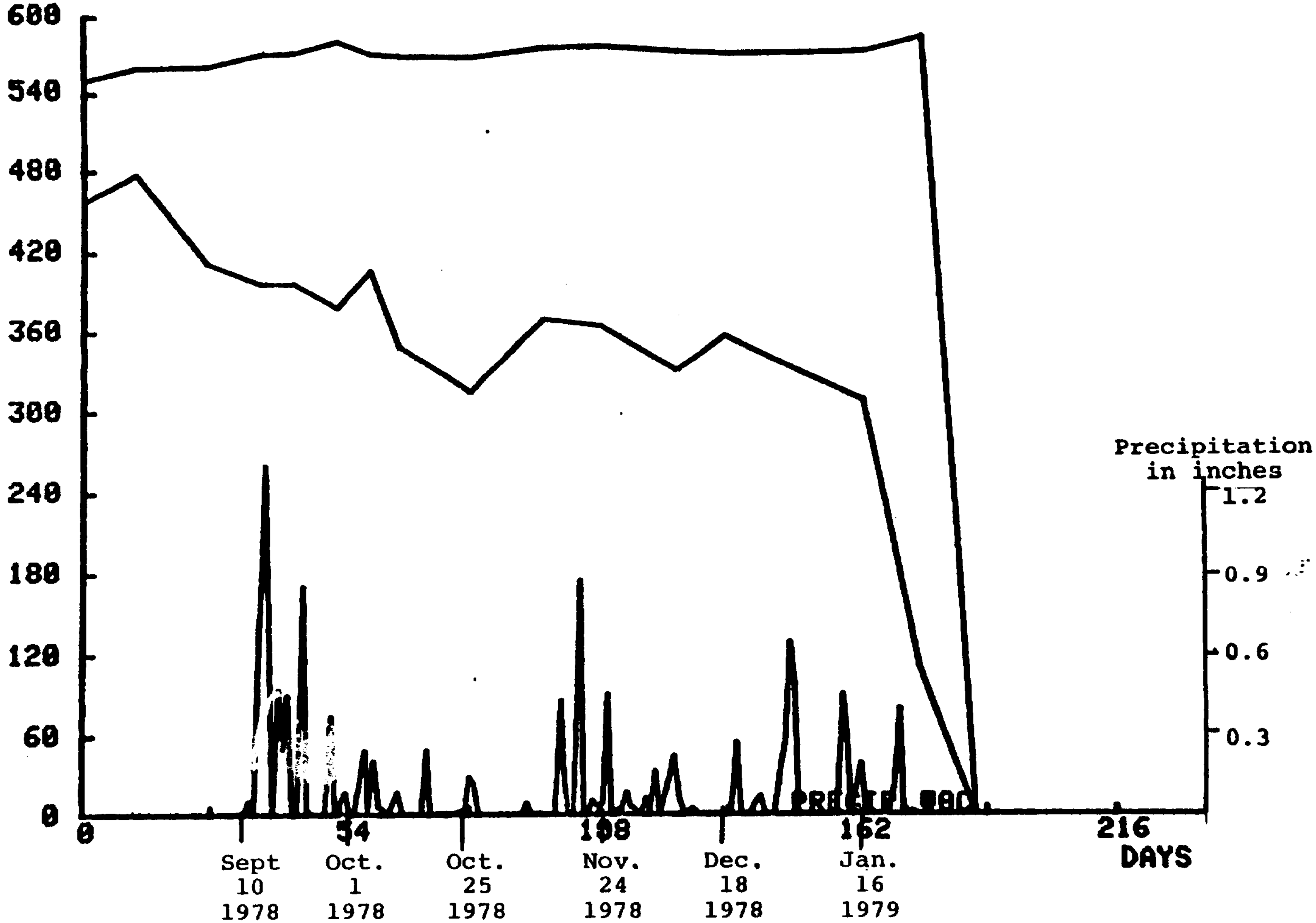


FIGURE 7

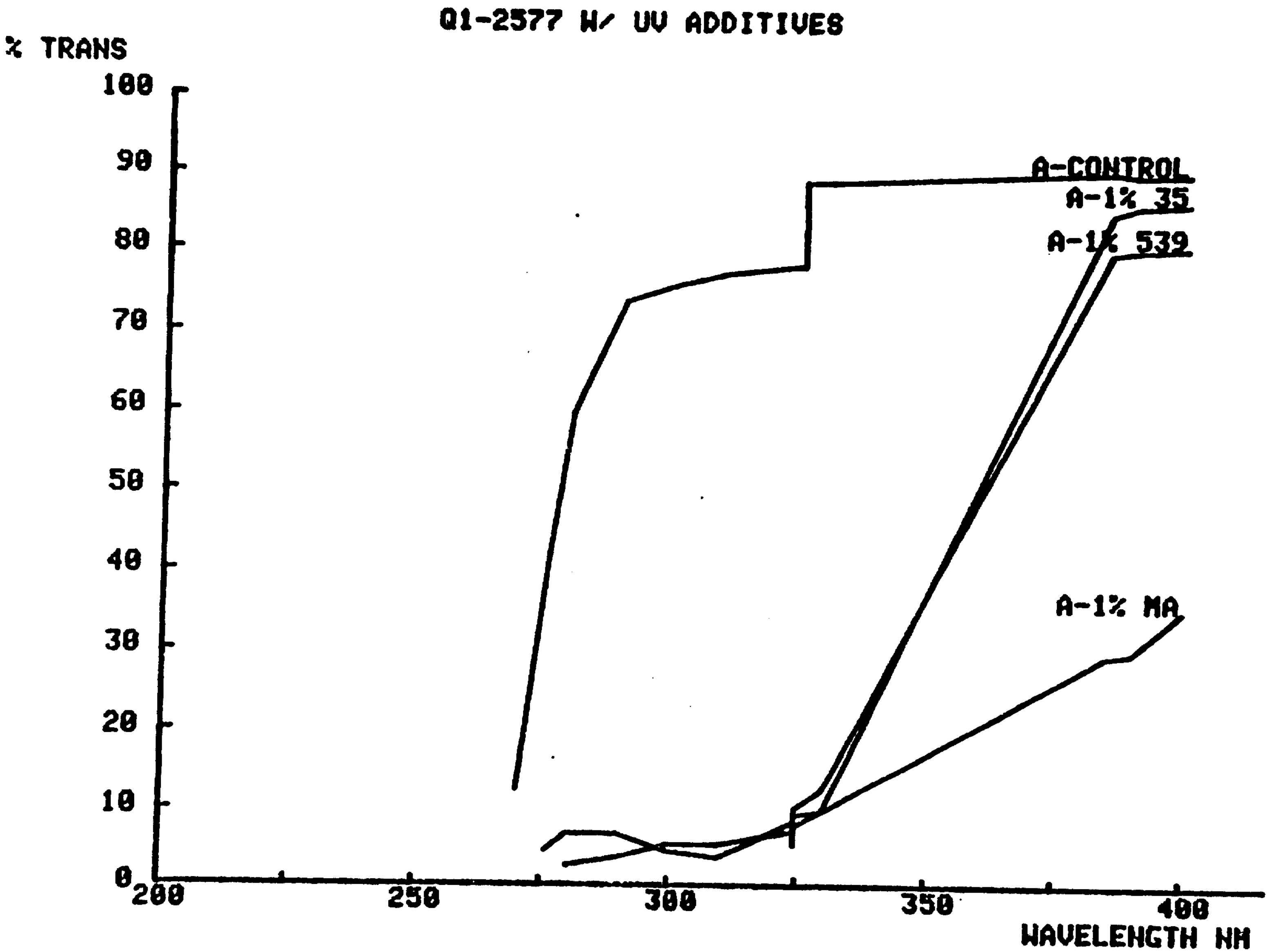

Q1-2577 W/ UV ADDITIVES
% TRANS
100
90
80
70
60
50
40
30
20
10
0
200
250
300
350
400
WAVELENGTH NM
A-CONTROL
A-1% 35
A-1% 539
A-1% MA

FIGURE 8

DC 840/B40N W/ UV ADDITIVES

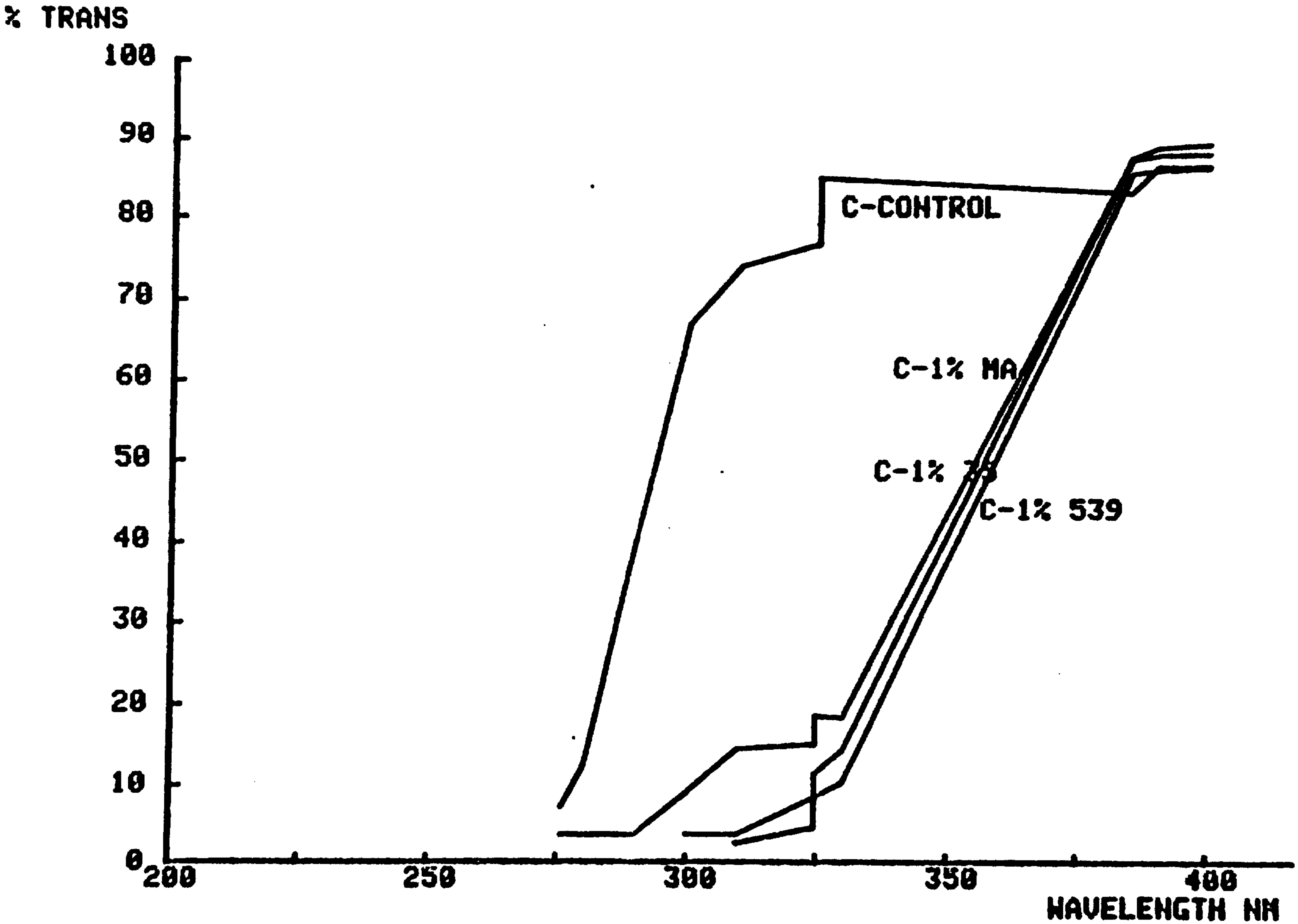
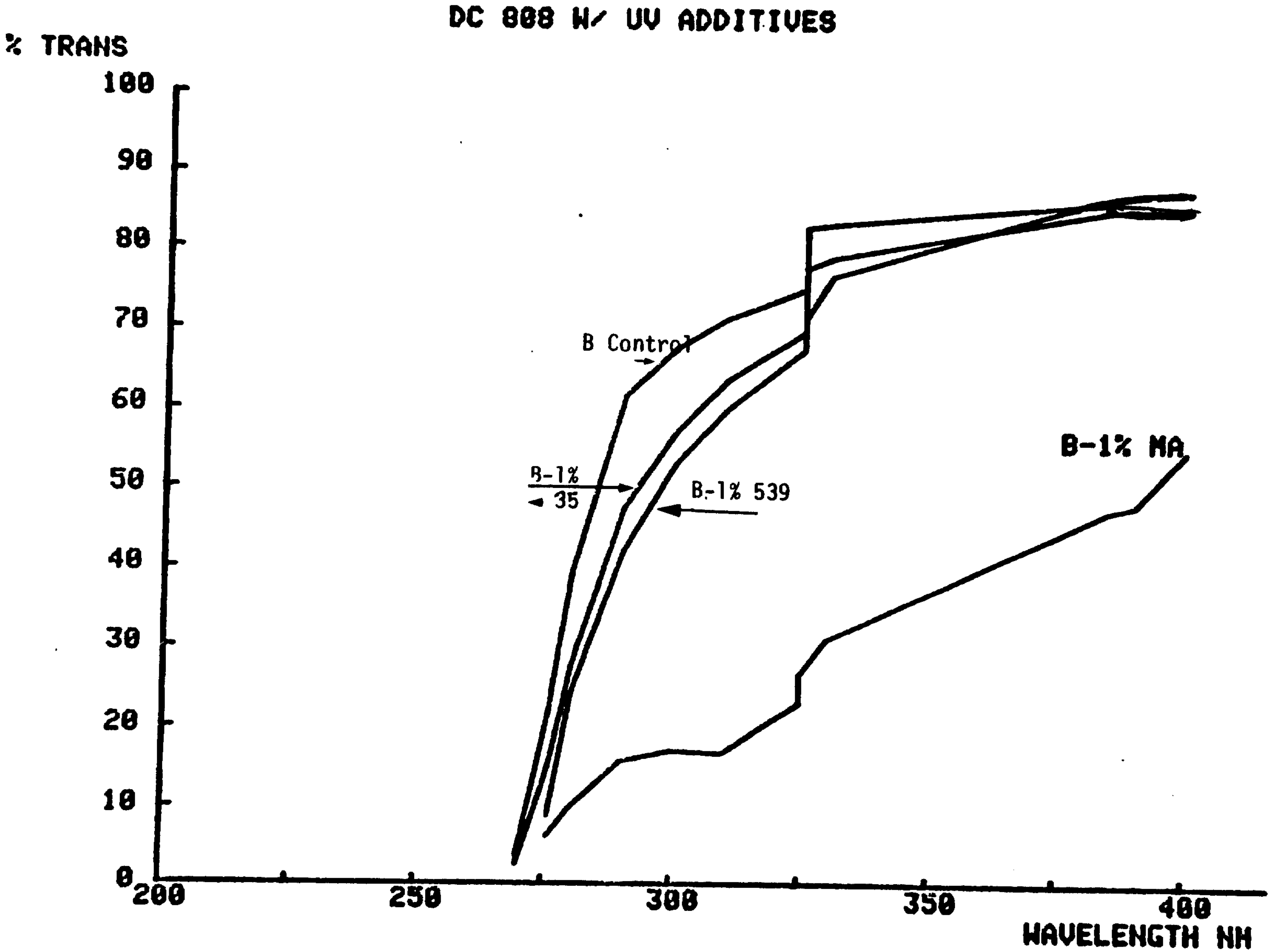
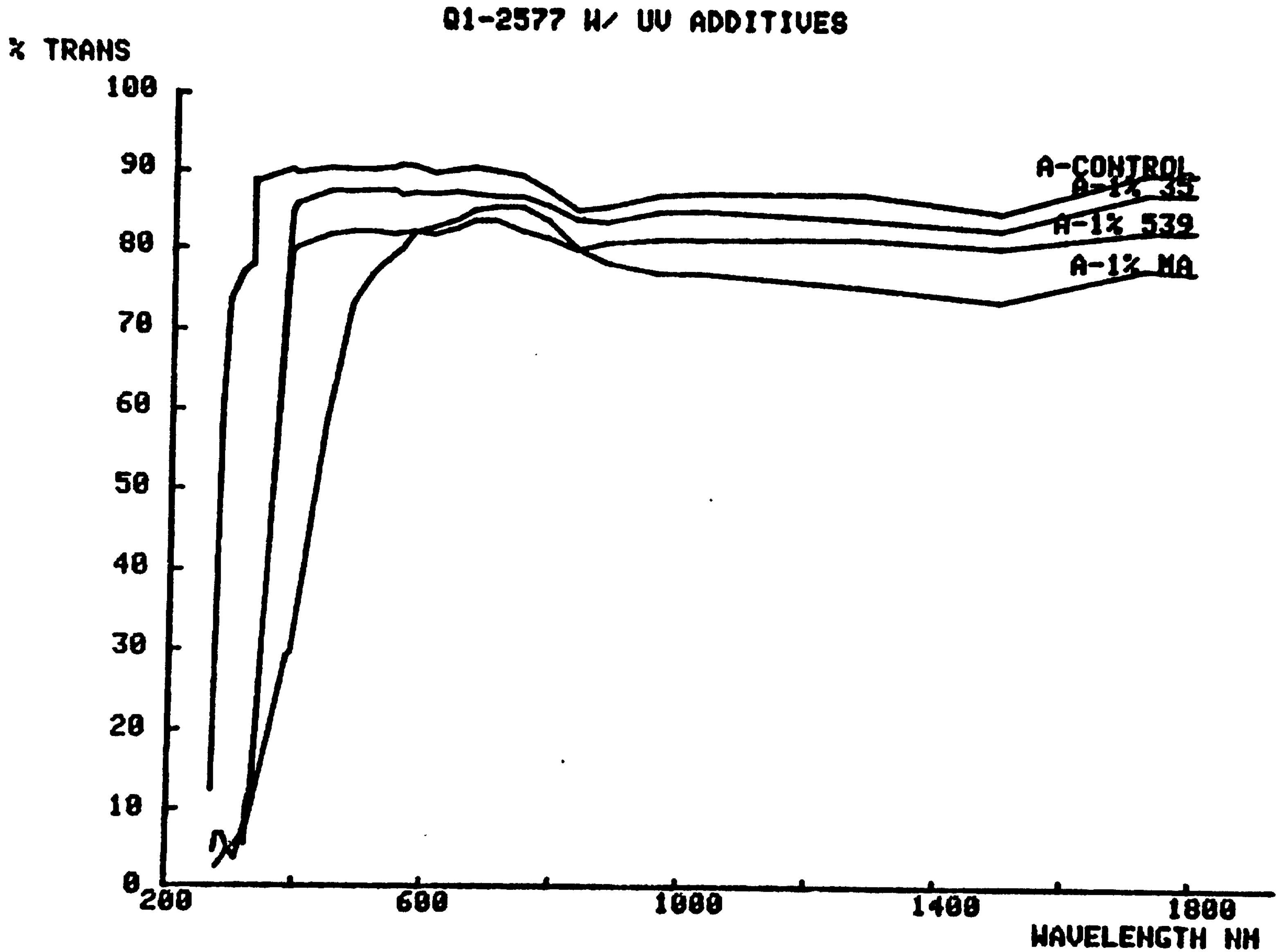


FIGURE 9



DC 808 W/ UV ADDITIVES
% TRANS
100
90
80
70
60
50
40
30
20
10
0
200
250
300
350
400
WAVELENGTH NM
B Control
B-1% 35
B-1% 539
B-1% MA

FIGURE 10



Q1-2577 W/ UV ADDITIVES
% TRANS
100
90
80
70
60
50
40
30
20
10
0
200
600
1000
1400
1800
WAVELENGTH NM
A-CONTROL
A-1% 35
A-1% 539
A-1% MA

FIGURE 11

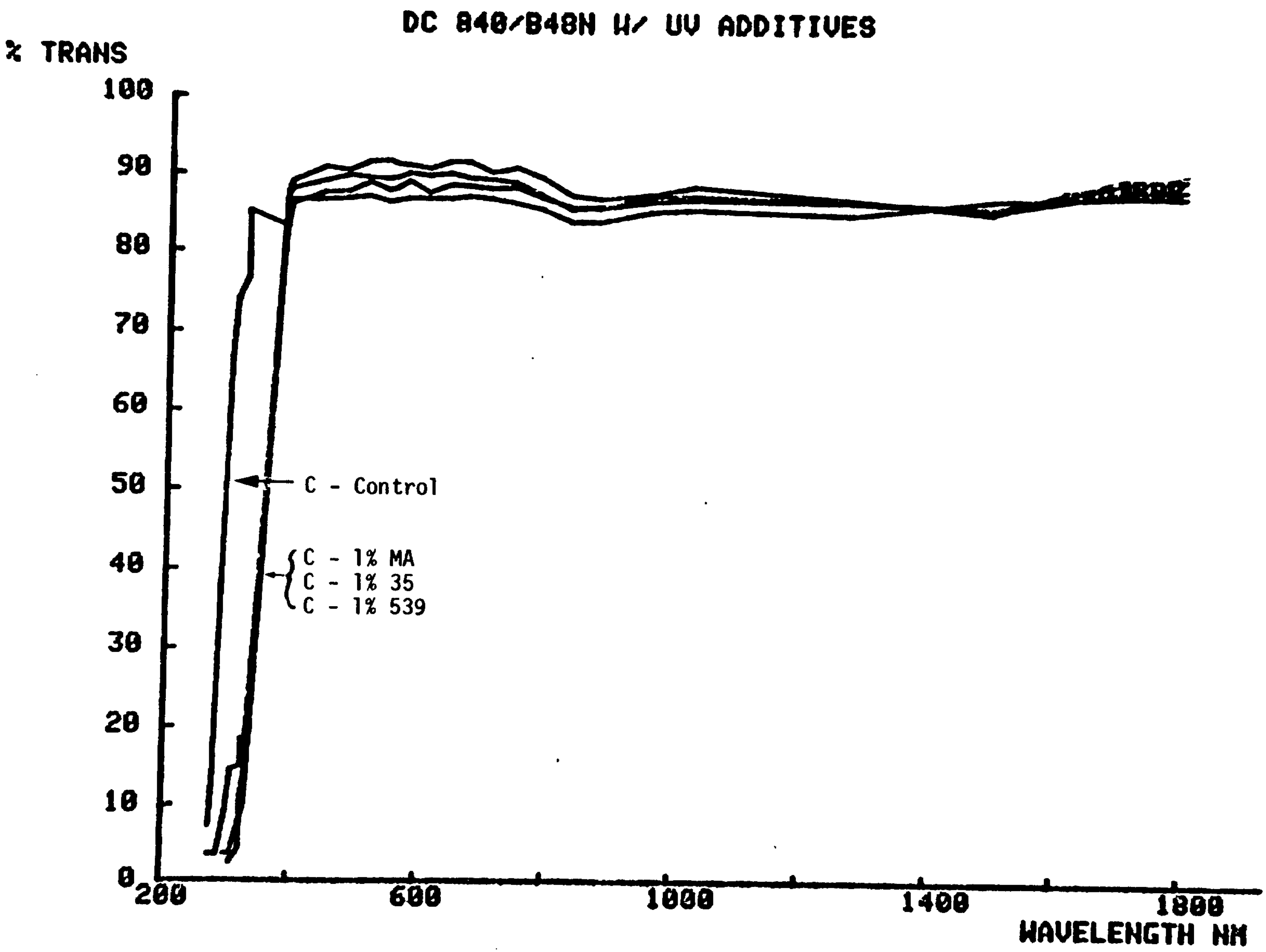

DC 840/B48N W/ UV ADDITIVES
% TRANS
100
90
80
70
60
50
40
30
20
10
0
200
600
1000
1400
1800
WAVELENGTH NM
C - Control
C - 1% MA
C - 1% 35
C - 1% 539

FIGURE 12

DC 808 W/ UV ADDITIVES